TWO CARBONIFEROUS BLASTOIDS FROM SCOTLAND

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ABSTRACT. The two fissiculate blastoids, *Astrocrinus tetragonus* (Austin and Austin, 1843) and *Hadroblastus*(?) *benniei* (Etheridge and Carpenter, 1886), occur together in Early Carboniferous Viséan (D) sediments of Scotland. *Astrocrinus* is a small, free-living eleutherozoic blastoid characterized by well-developed surface ornament. The nodes are interpreted as spine bases which, together with some brachioles, probably stabilized the animal on its substrate in periods of higher energy. *H.*(?) *benniei*, a stemmed blastoid formerly identified as *Phaenoschisma*? *benniei*, extends the known geographic range of *Hadroblastus* from North America to the British Isles, and the stratigraphic range into the Upper Viséan, if the species assignment is correct.

IN their definitive study of the blastoids in 1886, Etheridge and Carpenter listed three Lower Carboniferous blastoids from Scotland. The fragmentary nature of many of these has made their interpretation difficult. *Astrocrinus tetragonus* (Austin and Austin, 1843) is one of the very few free-living (eleutherozoic) blastoids; it is also found in England and Ireland. A second species, which is known only from Scotland, was originally described as *Phaenoschisma benniei* Etheridge and Carpenter, 1886. The third species was represented only by isolated ambulacra and thought to be a spiraculate blastoid (Etheridge and Carpenter 1886, p. 279; pl. II, figs. 38–42). Breimer and Macurda (1972) reviewed the first two species in a study of the phylogeny of the fissiculate blastoids. Because of its unique morphology, Austin and Austin (1843) erected the family Astrocrinidae for *Astrocrinus*, and it remains the only genus in this family. Breimer and Macurda (1972) described the internal structure of *A. tetragonus* and briefly discussed its growth and geographic occurrence. Etheridge and Carpenter (1886) discussed the nodes on the plates of *A. tetragonus* and concluded that they were perforate and probably bore a spine which articulated on them. Study of these nodes by scanning electron microscopy has shown them to be imperforate and of importance in deducing the life mode of the animal. Further preparation of specimens of *P. benniei* has shown that this species almost certainly belongs to the North American Mississippian genus *Hadroblastus* and thus extends its geographic range.

DIAGENESIS, BIOSTRATINOMY, AND PALAEOECOLOGY

The Scottish blastoids discussed herein have been collected from a sequence of Viséan D Zone limestones and calcareous shales. Etheridge and Carpenter (1886) listed their specimens as coming from the shales above No. 1 and No. 2 Limestones of the Lower Carboniferous Limestone group near Midlothian and Fife (*Astrocrinus*) and the Shale above the No. 2 Limestone in the East Salton and Kidlaw Quarries near Gifford, Haddingtonshire (*Hadroblastus*(?) *benniei*). Subsequent collections were made during the first part of the twentieth century by James Wright,

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whose collection is now in the Royal Scottish Museum. His material bears the locality labels 'Carlops, Peeblesshire' and 'No. 1 Bed, Invertiel, Fife'. These materials were apparently obtained as a by-product of Wright's study of *Allagecrinus* from the localities in the Lower Limestone Group (Wright 1941). George (1971) reviewed the stratigraphic complexities and biostratigraphy of the Lower Limestone Group. The Viséan–Namurian boundary occurs somewhere near the top.

The blastoids from the Lower Limestone Group are almost invariably crushed. This is not unexpected, as they are preserved in shales which underwent compaction. The thecae of *Astrocrinus* are compressed vertically and adjacent plates are strongly displaced. One frequent zone of failure is through the base of a theca along a line connecting the C and E ambulacra. This particularly obscures the relationships of the basal plates. *H.*(?) *benniei* is crushed flat and usually only partial thecae are recovered. Preservation in the shale, however, has had one beneficial effect. The skeletal microstructure (stereom) of echinoderms is an open lattice with numerous pores. Diagenetic calcite cements crystallize in optical continuity with the stereom and overgrow it externally. This most always obliterates surface detail, and the internal fabric is often disrupted. Preservation in fine-grained sediments instead of skeletal limestones may reduce the severity of the cementation process, resulting in excellent external and internal preservation of the blastoid stereom (e.g. Macurda 1973). The stereom is clearly evident within the plates of the specimen of *H.*(?) *benniei* in Plate 32, figs. 5, 8, when it is immersed in xylene. It is also evident on the surface of the plates of some specimens of *A. tetragonus* (Pl. 31, figs. 3, 6). The preservation of the surface detail on the plates of these blastoids is very good; this would suggest they are essentially preserved in the environment in which they lived. After death, they remained unburied long enough for the tissue binding the brachioles, ambulacral covering plates, and the stem in *H.*(?) *benniei*, to decompose, permitting disarticulation.

H.(?) *benniei* is a blastoid that is conventional in appearance and had a stem cicatrix. There is no morphologic evidence to indicate an unusual mode of life; it was probably a current-seeking (rheophilic) blastoid (Type I of Breimer and Macurda 1972). *A. benniei* is highly unusual. It is as though the lower half of the blastoid were stunted and grew to the side. It has a quadrate outline (Pl. 32, figs. 4, 7, 9), has no stem cicatrix, lacks any attachment scars, and thus was free living. The theca is always small (less than 10 mm) and even moderate oceanic swells or waves or tidal currents would exert a lifting force which would continually reorientate the animal, perhaps detrimentally. Thus it would appear to have lived in quiet or deep-water environments or might have had some special adaptations permitting it to cope with periods of higher environmental energy. The stratigraphic relationships of the Lower Limestone Group are not indicative of deeper water; the geographic extent of *Astrocrinus* and its local abundance suggest it was a functionally successful design. The ornament found on the surface of the plates is probably important in understanding the life mode of *Astrocrinus*. Most blastoid plates were secreted by deposition of calcite laterally along the edges of the plates, and growth lines are evident on the external surface. In *Astrocrinus* these are only occasionally evident on the sloping walls of the ambulacral sinus formed by part of the deltoid body and RD sector of the radial. Nodes occur on the upper part of the deltoid body along the crest and its sloping sides (Pl. 31, figs. 1, 3). They can have a row-by-row arrangement parallel to the radiodeltoid suture, suggesting formation as the plate grew aborally. Since their growth was upward, they represent deposition on the external surface, either contemporaneously with the growth-line formation or just subsequent to it. Those adjacent to sutures are of equal magnitude to those formed earlier and there is no gap as one approaches the radiodeltoid suture. The maximum diameter of the nodes is 0·15 mm and their height is about the same. There are approximately twelve radially disposed grooves on the side of each node; these terminate below the tip of each node. Nodes are also present on the upper half of the regular radials (above the aboral tip of the ambulacrum, external to the ambulacral sinus). Ornament on the lower half of the radials assumes a more linear appearance, the nodes assuming a laterally directed ridge-like aspect (Pl. 32, fig. 3). On the attenuated D radial and the bordering limbs of the C and E radials, ornament consists of sharp, linear ridges (Pl. 32, figs. 1, 2). These are nearly perpendicular to their respective sutures.

Articular surfaces between larger plates in echinoderms are usually characterized by non-porous stereom, as are the fulcral ridges of articulations in crinoids (Macurda and Meyer 1975) or the mammelons of echinoids (Jensen 1972). The surfaces on which small spines articulate in echinoderms are less obviously expressed in the stereom. Comparative study of the morphology of these surfaces should be helpful in determining the presence of spines in fossil echinoderms. The arms of the ophiuroid *Astrophyton* bear prominent spines used to snare prey, but the surface expression of the articulation of the spine with the arm is not well defined (Macurda 1976). The Devonian crinoid *Arthroacantha* bears spines on the surfaces of the basals and radials (e.g. Kesling and Chilman 1975, pl. 29, figs. 1–3). These spines may be at least 5·0 mm long and the diameter of the raised area where they articulate is only 0·3 mm. Without preserved spines, the raised areas would probably be merely interpreted as 'surface ornament'. It is tempting to suggest that each node of *Astrocrinus tetragonus* bore some type of spine and that the grooves on the side of each node represent points of insertion for muscles or ligaments to articulate the spine (Pl. 31, fig. 7). Etheridge (1876) reported and illustrated a microscopic spine adhering to one of his specimens by some particles of matrix, but it was not attached in place. No spines were observed during this study. The stereom of each node is apparently solid. Initially there are approximately six grooves (Pl. 31, fig. 2) but, as the node becomes larger, new grooves are inserted in intervening spaces. The tip of a node is a blunt, low hemispherical cap (Pl. 31, fig. 4). There is no differentiation of the stereom around the base of a node.

In the absence of the direct preservation of articulated spines, their presence in *Astrocrinus* remains speculative, but the morphology of the nodes is suggestive of their presence. The following discussion attempts to interpret the palaeoecology of *Astrocrinus* assuming their presence. The purpose of the spines was protective and they projected into the surrounding water. The animal sat on the substrate with the area beneath the D ambulacrum in contact with the substrate (see Pl. 32, figs. 4, 7, 9). The brachioles from the D sides of the C and E and the attenuated D ambulacra were splayed on to the substrate to help stabilize the organism in this position; the AB interarea projected uppermost. The linear ornament below the D ambulacrum also served to resist displacement due to waves or currents. (The D sides of the C and E ambulacra are wider than their opposite sides and less steep; this would have allowed the brachioles to project more nearly parallel to the substrate.) Spines borne in the EA, AB, and BC interareas on the body of the radials immediately below these interareas projected outward to form a protective forest of spines; some of those on the radial bodies may also have projected into the substrate. Thus, in spite of its small size, *Astrocrinus* could stabilize and position itself on the substrate through a combination of linear ornament, spines, and brachioles. The brachioles of the A and B ambulacra functioned normally but those of the D and parts of C and E were utilized to provide fixity for this free-living blastoid.

SYSTEMATIC PALAEONTOLOGY

Class BLASTOIDEA Say, 1825
Order FISSICULATA Jaekel, 1918
Family ASTROCRINIDAE Austin and Austin, 1843
Genus ASTROCRINUS Morris, 1843

1843 *Astracrinites* Austin and Austin, p. 110.
1843 *Astrocrinus* Morris, p. 49.
1848 *Zygocrinus* Bronn, p. 1381.

Type species. Astracrinites tetragonus Austin and Austin, 1843.

Astrocrinus tetragonus (Austin and Austin)

Plate 31, figs. 1–7; Plate 32, figs. 1–4, 7, 9; text-fig. 1

1843 *Astracrinites tetragonus* Austin and Austin, p. 110.
1843 *Astrocrinus tetragonus* Morris, p. 49.
1876 *Astrocrinites benniei* Etheridge, p. 103.

Scottish material. Royal Scottish Museum specimen numbers 1958.1.2355, 2360–2364, 2367, 2376, 2378–2380.

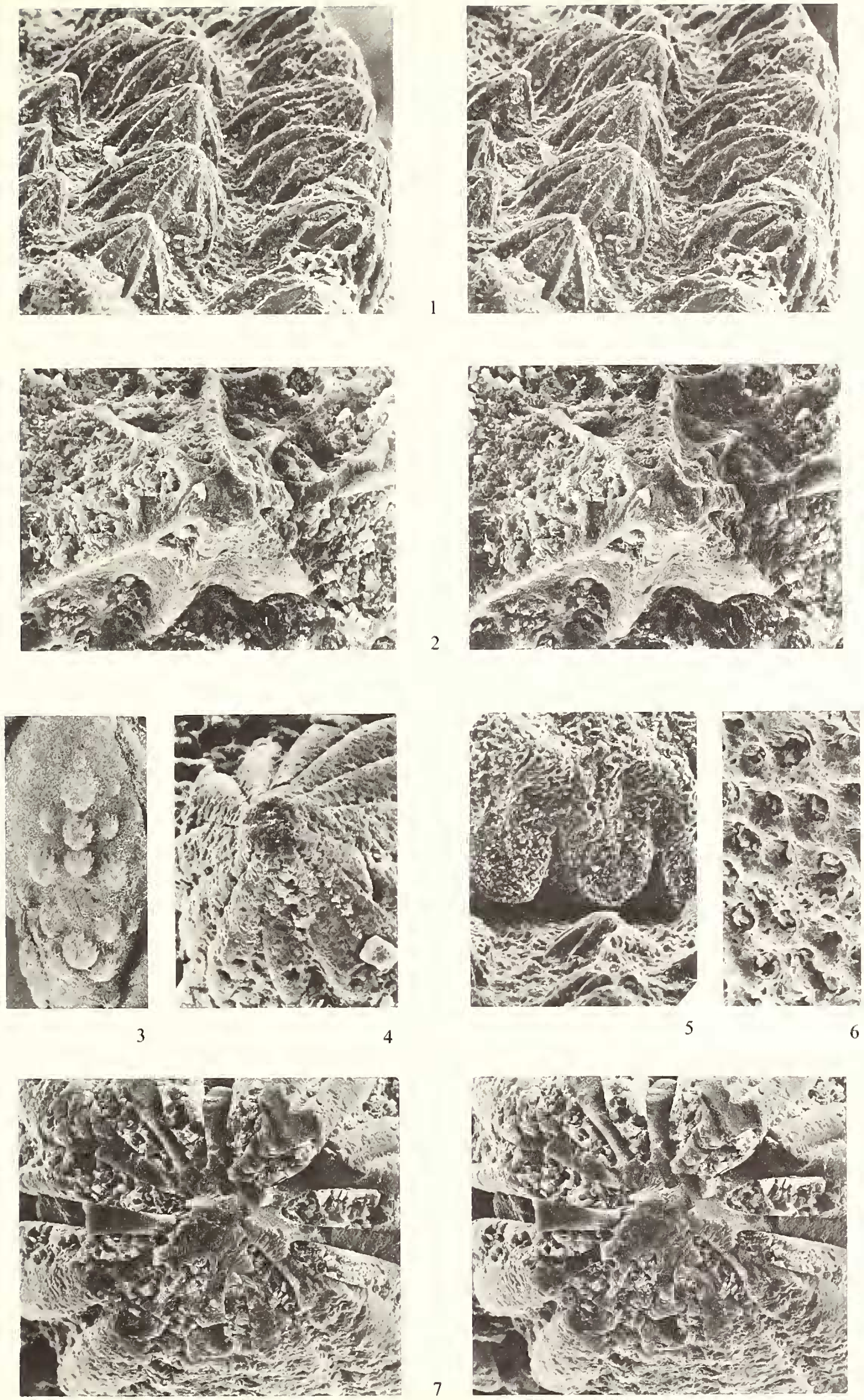
Description. Theca squat, ovoid in lateral view, pentagonal, asymmetric in oral view. Stem cicatrix lacking, animal being eleutherozoic with development of bilateral symmetry along plane of AB interarea and D ambulacrum (Pl. 32, figs. 4, 7, 9). AB, BC, and EA interareas protuberant, while CD and DE form a continuous, slightly convex arc in oral view due to shortened D ambulacrum. A and B ambulacra

EXPLANATION OF PLATE 31

Astrocrinus tetragonus (Austin and Austin, 1843); Lower Limestone Group, Lower Carboniferous; Carlops, Peeblesshire, Scotland. Scanning electron micrographs.

Figs. 1–7. 1, inclined view of nodes on deltoid, ×115; R.S.M. 1958.1.2363. 2, incipient node on deltoid, ×455; R.S.M. 1958.1.2363. 3, plan view of deltoid, oral direction at top, ×35; R.S.M. 1958.1.2380. 4, fully developed node on deltoid, ×350; R.S.M. 1958.1.2363. 5, brachiolar facets on edge of ambulacrum, oral direction to left, ×115; R.S.M. 1958.1.2363. 6, detail of stereom on wall of ambulacral sinus, ×685; R.S.M. 1958.1.2380. 7, fully developed node on deltoid with top broken off, ×455; R.S.M. 1958.1.2363.

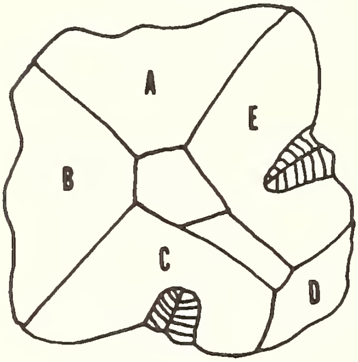
(R.S.M., Royal Scottish Museum.)



MACURDA, blastoids from Scotland

convex, set within broad shallow ambulacral sinus and extending to near base of theca; C and E ambulacra slightly longer, extending to base of outline in lateral view and visible in aboral view, recurving inward. D ambulacrum short, flat, confined to upper surface of theca. Length 2·32 mm; width, A–CD, 3·65 mm; AB–D, 4·48 mm.

Basalia two, extending from centre of aboral surface half-way up lateral surface beneath D ambulacrum (text-fig. 1). Outline elongate, narrow, pentagonal. No stem



TEXT-FIG. 1. *Astrocrinus tetragonus*, aboral view, Royal Scottish Museum specimen number 1958.1.2376, ×12. Compare with Plate 32, fig. 7. Radials A–E labelled. Drawn with camera lucida.

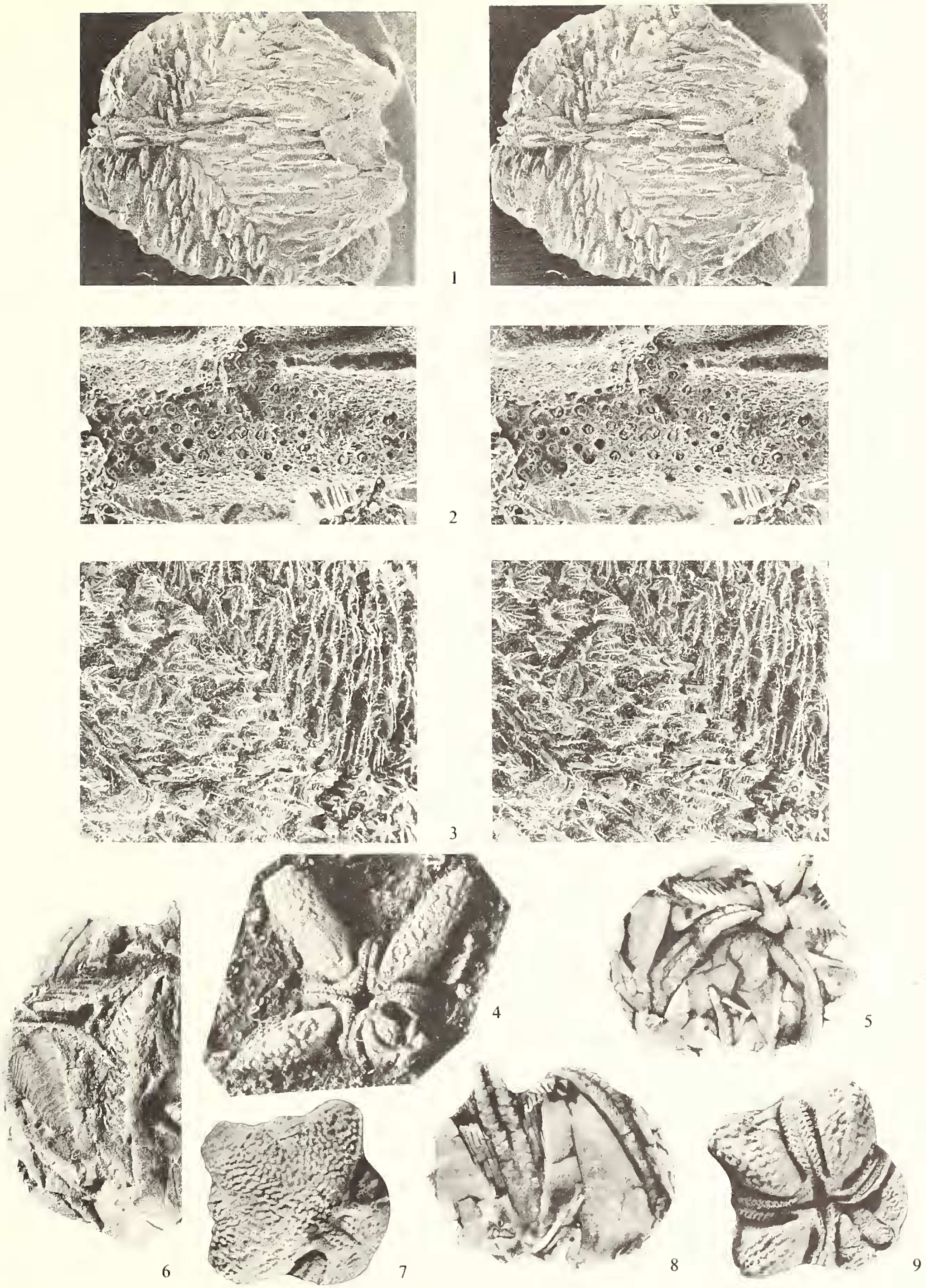
cicatrix. Basal on aboral surface flat, has two equal short edges against narrow bases of A and B radials (0·56 mm each); basal extending toward and narrowing slightly toward D ray. Edge against C radial of about equal length to A and B (0·48 mm), E about twice as long (0·88 mm); interbasal suture extends diagonally from a point near a centre line of E ambulacrum diagonally towards B side of C radial. Interbasal suture very slightly sinuous. Other basal convex in lateral view, quadrate in plan view, elongate (1·20 mm), with long edges against C and E radials and narrow edge against D radial half-way up lateral edge of theca; maximum width 0·40 mm. Lower basal ornamented with pustulose ornament, upper basal with a few irregular ridges parallel to long axis of plate (Pl. 32, fig. 1).

EXPLANATION OF PLATE 32

Figs. 1–4, 7, 9. *Astrocrinus tetragonus* (Austin and Austin, 1843). 1–3, Lower Limestone Group, Lower Carboniferous; Carlops, Peeblesshire, Scotland. 4, D_1 beds, Viséan, Lower Carboniferous; foreshore Oyster Bay, Fenit, Co. Kerry, Ireland. 7, 9, Lower Limestone Group, Lower Carboniferous, Invertiel, Fife, Scotland. 1, D deltoid (right side) and bordering C and E radials and basal (left centre), ×30; R.S.M. 1958.1.2361. 2, detail of ornament of D deltoid of fig. 1, ×285. 3, radial bodies, A right, B left, ×50; R.S.M. 1958.1.2363. 1–3, scanning electron micrographs. 4, oral view of specimen preserved on limestone surface, A ambulacrum at 9 o'clock, ×6; N.M.I. G.40.1965. 7, 9, aboral and oral views with A and B ambulacra at 12 o'clock respectively, ×7·5; R.S.M. 1958.1.2376. Specimens in 4, 7, and 9 coated with sublimate of ammonium chloride.

Figs. 5, 6, 8. *Hadroblastus*(?) *benniei* (Etheridge and Carpenter, 1886); Lower Limestone Group, Lower Carboniferous; Carlops, Peeblesshire, Scotland. 5, 8, inclined oral (centred on anal interarea) and lateral views of crushed specimen in xylene, ×4·8; R.S.M. 1958.1.2461. 6, left side of specimen in fig. 5 coated with sublimate of ammonium chloride, ×7·5.

(R.S.M., Royal Scottish Museum; N.M.I., National Museum of Ireland.)



MACURDA, blastoids from Scotland

Radials five, A and B of similar shape; D limbs of C and E truncated, and D reduced in size due to bilateral symmetry. A and B radials pentagonal in plan view with narrow base (0·52 mm), lateral sides diverge rapidly outward to maximum width at aboral tip of deltoids (2·92 mm), upper edges extend into ambulacral sinus at a right angle to axis of sinus. Radials A and B triangular in lateral view, being slightly convex from origin of radial outward in both an aboral and oral direction; lower edge slightly concave. RB sector narrow, straight both parallel and perpendicular to RB axis; RB growth front straight (RB 1·64 mm; RBF 0·26 mm). RB sector merges smoothly with RR sector. Latter is very slightly convex parallel to and strongly convex perpendicular to RR axis; RR growth front straight (RR 1·20 mm; RRF 2·84 mm). RB and RR sectors ornamented with nodose ornament or discontinuous linear ridges. No growth lines visible. RD sector at sharp angle to RR sector, forming part of ambulacral sinus, slightly convex parallel to and straight perpendicular to RD axis. RD growth front very slightly convex (RD 1·60 mm; RDF 1·28 mm). Outer part of ambulacral sinus ornamented with nodose ornament; inner part smooth. AB interarea slightly larger than AE or BC. C and E radials similar except RB sectors much shorter with much longer radial–basal suture, and D side of each is about one-half the size of the other half due to the truncate D ambulacrum. No ambulacral sinuses along D sides of C and E radials. D limb of E radial in contact with DE deltoid along narrow suture bordering ambulacrum; D limb of C radial in contact with hypodeltoid. D radial small, relatively flat. RB sectors (RB 1·44 mm; RBF 0·04 mm) and lower half of RR sectors similar in size to those of A and E radials but upper part of RR sectors and RD sectors much shortened and reduced, bordering reduced D ambulacrum (RR 1·08 mm; RRF 1·36 mm; RD 0·72 mm; RDF 0·60 mm). D radial beneath ambulacrum and bordering limbs of C and E radials; discontinuous linear ridges perpendicular to radial and radial-basal sutures (Pl. 32, figs. 1, 2).

Deltoids four; three of equal size, DE reduced. Regular deltoid rhombic in plan view, convex in lateral view. Deltoid lip small, hexagonal with edge bordering oral opening and interdeltoid sutures bearing ambulacral tract, sloping downward towards plate edges. Deltoid lip constricts aborally along deltoid–ambulacral suture to adoral end of hydrospire clefts. Central portion of deltoid lip flat, being higher than ambulacral tracts and hydrospire clefts. Deltoid body rhombic in outline, expanding aborally from narrow constriction of deltoid at adoral ends of hydrospire clefts. Body bordered laterally by hydrospire clefts and aborally by radiodeltoid sutures; all of these edges straight (Body L. 1·80 mm). Plane of radiodeltoid sutures nearly horizontal. Deltoid body convex lengthwise, with greatest height being in median position along a rounded crest. Axis of crest may be ornamented by nodes along centre of crest (Pl. 31, fig. 1) or these may merge to be a semicontinuous ridge. Sides of deltoid body slope steeply downward into ambulacral sinus, ornamented by nodes which may form a row paralleling the crest. Broad growth lines may be visible parallel to radiodeltoid suture. Body smooth near ambulacra. As on radial, a node has a blunt top but the base is fluted by parallel grooves. (Del. L. 2·40 mm; Gr. Ad. W. 0·56 mm; Min. W. 0·40 mm; Gr. Ab. W. 1·28 mm; DR 1·40 mm.)

DE deltoid smaller, asymmetrical. Deltoid lip as for other deltoids, body much reduced because of asymmetry. Form of DE deltoid body similar to that of regular body but about one-third its size; radiodeltoid suture with D radial long whereas that with E radial short. Furthest aboral extension of deltoid thus near to ambulacrum (Body L. 0·64 mm; Gr. Ab. W. 0·52 mm).

Anal deltoids four: a superdeltoid bordering oral opening, two cryptodeltoids (internal) and a hypodeltoid. Size of superdeltoid similar to deltoid lip of regular deltoid. C cryptodeltoid large, D cryptodeltoid small. Hypodeltoid a relatively large plate, pentagonal, with concave adoral edge bordering anus, two straight lateral edges bordering C and D ambulacra, and slightly convex radial-hypodeltoid sutures; D side of plate larger. Plate relatively flat, slopes downward from D to C ambulacrum. Some nodal ornament (HD L. 0·48 mm; W. 0·88 mm).

Ambulacra five; D much shortened and reduced. Normal ambulacra linear in plan view, convex in lateral view. A and B ambulacra (L. 2·0 mm) curve through 90° while C and E ambulacra (L. 2·4 mm) curve through 120° and are visible in aboral view. Aboral tips of C and E ambulacra more closely approach each other (1·40 mm) than do aboral tips of A and B ambulacra (2·20 mm; Pl. 32, fig. 7). A and B ambulacra in ambulacral sinus. B side of C ambulacrum and A side of E ambulacrum also have sloping wall of sinus but D sides flush with bordering radials. Ambulacra convex in cross-section (W. 0·68 mm) with median depression along ambulacral tract. Lancet exposed along median adoral two-thirds of ambulacrum. Brachiolar facets along lateral sloping sides of ambulacrum (Pl. 31, fig. 5). Side plates seven per mm, quadrate, with slightly convex admedial edge and straight aboral edge. Adoral abmedial edge of plate embayed by triangular outer side plate. Edge of side plate against next adoral side plate straight as is adoral suture against outer side plate. Laterally side plate tapers to a point or narrow rounded tip. Outer side plates widest along lateral edge of ambulacrum. Brachiolar facet ovoid, formed equally from side plate (aboral half) and outer side plate (adoral half) (L. 0·14 mm; W. 0·12 mm).

D ambulacrum short (L. 1·2 mm), lanceolate in plan view (W. 0·48 mm), flat in lateral view, convex in cross-section. Less than half of lancet exposed in adoral half of ambulacrum.

Ambulacra separated from adjacent radials and deltoids by hydrospire clefts which extend full length of the ambulacrum and provide entrance to the ten hydrospire groups. Two hydrospires per group except in those of anal interarea and E side of D ambulacrum, where there is only one.

Oral opening pentagonal, bordered by four deltoids and superdeltoid (W. 0·28 mm). Adoral edges of plates bearing minor grooves of ambulacral tract.

Remarks. The description of the external morphology is derived from R.S.M. 1958.1.2376 (Pl. 32, figs. 7, 9), and measurements cited above pertain to this specimen. A previous repository and locality citation for this specimen (Breimer and Macurda 1972, pl. XI, figs. 4, 7) was incorrect. Details of the super- and cryptodeltoids and hydrospires are summarized from Breimer and Macurda 1972.

Abbreviations for plate descriptions and measurements are given in Breimer and Macurda 1972. Micrographs were taken with a Japan Electron Optic-Laboratory Model JSM-U3 scanning electron microscope. Specimens were coated with 500 angstroms of gold and photographed with Polaroid PN type 55 film at 15 KV.

Family NEOSCHISMATIDAE Wanner, 1940
Genus HADROBLASTUS Fay, 1962

Type species. H. convexus Fay, 1962.

Hadroblastus(?) *benniei* (Etheridge and Carpenter)

Plate 32, figs. 5, 6, 8

1886 *Phaenoschisma benniei* Etheridge and Carpenter, p. 278, pl. II, fig. 37; pl. IV, figs. 5, 6.
1972 ?*Phaenoschisma benniei* Breimer and Macurda, p. 18, pl. V, figs. 8, 11, 13.

Scottish material. British Museum (Natural History) specimen numbers E666, E1114, E1115; Royal Scottish Museum specimen number 1958.1.2461.

Description. Theca small, biconical, vault and pelvis subequal. Pelvis conical, broad; vault low, with break in profile at junction of radial and deltoids. Cross-section pentagonal (at angular tip of ambulacra); greatest width median at aboral tip of ambulacra. Height and width subequal, near 10 mm or less.

Basals one-half of conical pelvis, pentagonal in plan view, very slightly concave in lateral profile. Stem cicatrix small, at very base of theca. Azygous basal not preserved. Zygous basal pentagonal in plan view with straight edges. Median and lateral BR sectors very slightly concave parallel to BR axis; median convex, lateral straight normal to BR axis. Adjacent sectors merge smoothly. Growth lines strong. Typical ZBL 1·8 mm; ZBW 2·0 mm; ZBOPt 2·1 mm; ZBBR 1·7 mm; ZBBRF 1·0 mm.

Radial pentagonal in plan view. Lower edge radial convex, lateral edges slightly convex, top straight, slightly concave inward. In plan view ambulacral sinus occupies one-half of upper part of radial. In lateral profile radial V-shaped with upper two edges subequal, straight profile, lower edge concave. RB sector straight or very slightly convex parallel to RB axis, slightly concave normal to it, merges smoothly with RR sector. Latter straight parallel to RR axis and convex normal to it. RD sector grew mostly within an ambulacral sinus, straight parallel and normal to RD axis. Narrow external RD growth sector borders ambulacral sinus. Striated ornament (growth lines) paralleling sutures in RB, RR, and external part of RD sectors; small double U-shaped lip at aboral end of ambulacrum at origin of radial. Hydrospires occupy full width RD sector until eight or nine hydrospires formed.

Deltoid hexagonal in plan view with straight DD, concave DAF, and straight DRF. Deltoid slightly convex to very slightly concave in lateral profile, with crest forming dominant part of plate. Adoral edge of plate (deltoid lip) prominent, with adorally directed V-shaped rim bordering ambulacral tract. Deltoid crest originates just behind small depression paralleling adoral rim. Crest sharp, directed downward from oral opening. Sides of crest slope moderately downward, with hydrospire slits across DRF until eight to nine hydrospires formed. Formation of hydrospires then ceases and deltoid crest bifurcates in median part of deltoid body to form two aborally diverging ridges which border ambulacral sinus. Median aboral part of deltoid body rhombic, concave in cross-section.

Number of anal deltoids unknown. Relatively large hypodeltoid with external growth sector present. Hypodeltoid pentagonal, with straight lateral borders and convex hyporadial sutures, each with an aborally directed angular bend in the middle.

Ambulacra five, sublanceolate in plan view, slightly convex in lateral view extending half-way down theca. Ambulacrum convex in cross-section, with median depression along ambulacral tract. Lancet narrowly exposed, apparently over most of the ambulacral length. Three side plates per mm. Aboral lateral edge of each side plate embayed by a large triangular outer side plate. Side plate pentagonal with straight adoral edge which intersects median line of ambulacrum at an angle; convex admedial edge; straight aboral medial edge which parallels adoral edge; straight aboral lateral edge against outer side plate, and narrow, slightly convex lateral edge which forms part of outer edge of ambulacrum. Large elliptical brachiolar facet on outer sloping side of ambulacrum (Pl. 32, fig. 6), formed equally on side plate (aboral half) and outer side plate (adoral half). Arcuate trough borders aboral margin of brachiolar facet. Four or five minor grooves per side plate border main ambulacral groove; present also on adoral margin of ambulacral side grooves.

Ten(?) hydrospire groups. Maximum of eight to nine in regular groups, bordering ambulacrum in shallow ambulacral sinus. Some visible on C side of anal interarea, presumed to be present on D side as well (R.S.M. 1958.1.2461). Number apparently reduced in anal interarea.

Stereomic microstructure is well preserved in some specimens.

Remarks. The above description is a composite taken from specimens in the Royal Scottish Museum and the British Museum (Natural History). The specimens are crushed and fragmentary, precluding accurate measurement, and only a few have been recovered.

Etheridge and Carpenter (1886) originally described this species as *Phaenoschisma benniei*. Breimer and Macurda (1972) listed this assignment with a question mark. Restudy and further preparation of the material from the Royal Scottish Museum revealed agreement on almost all determinable characters with the definition for *Hadroblastus* given by Breimer and Macurda (1972). The number of anal deltoids is unknown in *H.*(?) *benniei* and the form of the aboral part of the deltoid body is different from the North American species of *Hadroblastus*. Lack of information on the anal deltoids would appear to be the only character precluding definite assignment to *Hadroblastus*. An incomplete blastoid from beds of C_2S age near Dublin, Ireland was questionably identified as *Hadroblastus* sp.? by Breimer and Macurda (1972). If assignable to *Hadroblastus*, *H.*(?) *benniei* would represent the youngest occurrence of the genus, being D_2 in age.

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